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Qualitative and Quantitative Variation in Starch from Four Species of *Curcuma*

Pady Kumaran Sajitha and Bhaskaran Sasikumar*

Division of Crop Improvement and Biotechnology, Indian Institute of Spices Research, Kozhikode-673012, Kerala, India

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Summary The starch content (dry weight basis) from *Curcuma amada* Roxb., *C. aromatica* Salisb., *C. caesia* Roxb., and *C. xanthorrhiza* Roxb. was 45.24–48.48% (w/w), and the four species differed significantly in terms of ash content and the swelling power, solubility, and water-holding capacity of starch. *Curcuma amada* recorded the maximum swelling power, solubility, and water-holding capacity, whereas *C. caesia* recorded the lowest values for these parameters. Scanning electron micrographs revealed variation in the shape and size of starch granules as follows. *Curcuma amada*: oval to elliptical with a smooth surface, 16–48 μm long and 11–26 μm wide; *C. aromatica*: oval to elliptical, flat with concentric rings on the surface, 9–60 μm long and 6–24 μm wide; *C. caesia*: round to oval with a smooth surface, 10–39 μm long and 9–23 μm wide; *C. xanthorrhiza*: elongated, 9–47 μm long and 8–23 μm wide.

Key words Black turmeric, Mango ginger, Physicochemical property, SEM, Yield.

The genus *Curcuma* (family Zingiberaceae) includes more than 80 species of rhizomatous herbs widely distributed in the tropics in Asia, Africa, and Australia (Sasikumar 2005). Besides their use as a spice and in medicine, many *Curcuma* species are a rich source of starch, a major dietary source of energy for people (Policegoudra and Aradhya 2008). However, the genus has not been adequately exploited as a source of starch (Rajeevkumar *et al.* 2010).

Starch in plants occurs as granules with characteristic shapes and sizes, and these attributes influence its suitability for specific uses (Rani and Chawhaan 2012). Currently used sources of starch, such as potato, yams, and cassava, may need to be supplemented in the future because they are overexploited by the industry, which makes it prudent to explore alternative sources of starch. Many *Curcuma* species including *C. caulina*, *C. angustifolia*, *C. montana*, *C. pseudomontana*, *C. zedoaria*, *C. malabarica*, *C. decipiens*, *C. rubescens*, and *C. haritha* are reported to be such potential sources (Velayudhan *et al.* 1999) but many more are likely to be equally promising. The present investigation studied four such species and focused on the structural characteristics and some physicochemical properties of their starch and starch yield. The species were *C. amada* Roxb., *C. aromatica* Salisb., *C. caesia* Roxb., and *C. xanthorrhiza* Roxb.

Curcuma amada, often referred to as 'mango ginger' owing to its characteristic odour similar to that of raw mangoes, has culinary and medicinal applications and is also used as a source of starch (Policegoudra *et al.* 2011). *Curcuma aromatica*, or wild turmeric, is known for its use in toiletries and for its medicinal uses and is also a source of starch (Al-Reza *et al.* 2010). *Curcuma caesia*, also referred to as black turmeric because of its unique bluish-black rhizomes, is highly prized for its putative medicinal properties; it is used in treating sprains, bruises, and several other ailments (Pandey and Chowdhury 2003). *Curcuma xanthorrhiza* is used in traditional medicine for

* Corresponding author, e-mail: bhaskaransasikumar@yahoo.com
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treating inflammation and premenopausal bleeding (Jarikasem *et al.* 2005).

Materials and methods

Isolation of starch granules

Starch was extracted by combining the methods of Rani and Chawhaan (2012) and Zhou *et al.* (2013) with slight modifications. Fresh but mature rhizomes were washed, peeled, and immediately sliced into 2–3 cm cubes. The cubes were suspended overnight in a 0.1% solution of sodium bisulphite in water. The samples were homogenized in 1% solution of ammonium oxalate in water. Cell debris was removed from the homogenate by filtering through two layers of muslin cloth, and the filtrate was kept aside for the starch to settle to the bottom as sediment. The extraction process was repeated three to four times until all the starch was extracted from the material.

The sediment was suspended in saline (0.9%) solution at room temperature and shaken after adding toluene (0.1% by volume) to denature any residual cytoplasmic proteins. The starch settled to the bottom, and the layer consisting of proteins and toluene was discarded. Any brown layer that formed at the top was also discarded, and the white layer was re-suspended in water and centrifuged several times (3000 rpm, 10 min) until the supernatant was free of colour and no more brown layers were formed. The starch sediment was rinsed with 70% ethanol followed by 80% acetone and ether. Finally the samples were dried at room temperature.

Examination of starch granules under a scanning electron microscope

The extracted starch was serially dehydrated in a series of progressively stronger solutions of ethanol (30, 50, 70, and 90%). Gold coating tape was pasted on the circular stub of a scanning electron microscope (SEM) and the starch granules to be examined were sprinkled on the stub. The stub with sample was then coated with gold for 1 min by using a gold-coating machine and viewed under a scanning electron microscope (Hitachi SU 6600 FE). The size of starch granules was measured and the granules were photographed using a camera attached to the SEM.

Estimation of starch by anthrone reagent

The starch samples were treated with 80% alcohol to remove sugars and the starch was extracted with perchloric acid. The suspension was examined with a spectrophotometer (green to dark green at 630 nm) (Hodge and Hofreiter 1962).

Moisture content and ash content

Moisture content and ash content of the starch were determined using the standard AOAC official procedures (Helrich 1990).

Solubility and swelling power

The solubility of the samples was recorded at 85°C by using the method of Ju and Mittal (1995) and swelling power by the method of Leach *et al.* (1959).

Water-holding capacity

Water holding capacity (WHC) of the samples was determined by using the method of Ju and Mittal (1995).

Results and discussion

The starch granules of the four *Curcuma* species varied greatly in shape and size (Fig. 1 and Table 1). *C. aromatica* granules were the largest, showed surface ornamentation, and were different

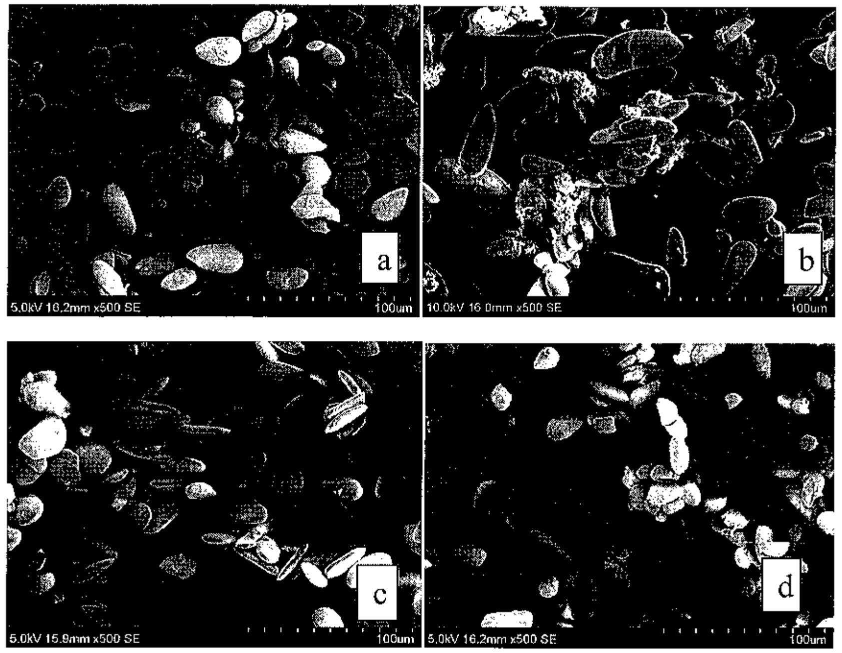

Fig. 1. Scanning electron micrograph of starch granules of four *Curcuma* species. a) *C. amada*, b) *C. aromatica*, c) *C. caesia*, and d) *C. xanthorrhiza*.

Table 1. Mean size and shape of starch granules of four *Curcuma* species.

Species	Scanning electron microscopy		
	Size		Shape
	Length (μm)	Width (μm)	
C. amada	16–48	11–26	Oval to elliptical, smooth surface
C. aromatica	9–60	6–24	Oval to elliptical, large, flat with concentric rings
C. caesia	10–39	9–23	Round to oval, small, smooth surface
C. xanthorrhiza	9–47	8–23	Oval to elliptical, some were rounded, with smooth surface

from the granules of the rest of the species in having concentric rings. Earlier SEM studies in different *Curcuma* species also report wide variation in the size and shape of starch granules: elliptical and 14–46 μm long in *C. zedoaria* and 16–42 μm in *C. malabarica* (Jyothi *et al.* 2003); oval, irregular or cuboidal or elliptic and polygonal in *C. amada*, either small (3–20 μm long) or large (20–48 μm long) (Policegoudra and Aradhya 2008); ranging in length from 6 to 25 μm in *C. malabarica*, *C. longa*, *C. sylvatica*, *C. caesia*, *C. zedoaria*, *C. raktakanta*, *C. aeruginosa*, and *C. aromatica* (Vimala and Nambisan 2005) and from 20 to 25 μm in *C. longa* and 20 to 30 μm in *C. zedoaria* (Leonel *et al.* 2003); small, rounded, oval to elliptical or spherical, 3.32–32.55 μm long and 2.29–8.47 μm wide in *C. angustifolia* (Rani and Chawhaan 2012).

The physiology of a plant and its chloroplasts and amyloplasts influence the morphology of starch granules (Singh *et al.* 2003). Earlier studies in potato, yam, ginger, cassava, and some other *Curcuma* species have shown that starch granules vary considerably not only with species but also with location (Braga *et al.* 2006, Zhou *et al.* 2013).

Starch yield (dry basis, w/w) in the present experiment ranged from 45.24% in *C. caesia* to 48.48% in *C. amada* (Table 2) and, in *Curcuma* species such as *C. aromatica* and *C. amada*, is

Table 2. Yield and physicochemical properties of starch of four *Curcuma* species.

Species	Starch (%)	Moisture (%)	Ash (%)	Solubility (%)	Swelling power (g/g)	Water holding capacity (%)
C. amada	48.48±0.31	9.22±0.08	4.58±0.01	1.21±0.02	4.48±0.04	157.72±0.85
C. aromatica	45.90±0.10	9.26±0.08	11.45±0.02	1.09±0.02	3.96±0.05	133.33±0.51
C. caesia	45.24±0.25	8.94±0.09	3.55±0.02	0.47±0.01	3.74±0.04	121.62±0.79
C. xanthorrhiza	46.11±0.18	9.60±0.12	3.83±0.04	1.07±0.02	4.07±0.01	142.50±0.42

known to vary with location, maturity, accession, etc. from 9.20 to 45.0% (Srivastava *et al.* 2007, Angel *et al.* 2008, Policegoudra and Aradhya 2008, Bhende *et al.* 2013).

The four species did not differ a great deal in terms of their moisture content (8.94–9.60%; dry basis, w/w) (Table 2). Moisture content of dry tuber starch is usually in 6–16% (Moorthy 2002). Policegoudra *et al.* (2011) reported 9.8% moisture in *C. amada* and Braga *et al.* (2006) reported a figure of 11.8% in *C. longa*. Ash content was maximum in *C. aromatica* (11.45%) and minimum in *C. caesia* (3.55%).

The solubility and swelling power of starch granules are positively correlated, implying that solubilization increases with the extent of swelling (Srichuwong *et al.* 2005), which is borne out in the present experiment as well; *C. amada* topped in terms of both solubility and swelling power. The swelling power of starch granules is also reported to be influenced by hydrogen bonding and the structure of amylopectin molecules (Tester *et al.* 1993, Hoover 2001). The solubility and swelling power of starch granules indicate the strength of the binding force between granules, which ultimately decides the suitability of starch from a given source for a specific purpose. Low solubility is attributed to the amylose–lipid complex in starch granules, which lowers their swelling power (Leach *et al.* 1959).

The water-holding capacity of starch granules depends on the extent of swelling and is thus directly influenced by solubility and swelling power. A loose association between amylose and amylopectin molecules in starch granules is believed to increase their water-holding capacity (Soni *et al.* 1987). Wotton and Bamunuarachchi (1978) attributed the variation in water-holding capacity to the difference in available water-binding sites in starch granules. The morphological structure of granules also influences their swelling power, solubility, and water-holding capacity (Zhou *et al.* 1998, Singh and Singh 2001, Kaur *et al.* 2002).

Conclusion

Although the four *Curcuma* species did not differ significantly in terms of starch yield and moisture content, they did show qualitative differences in size, shape, solubility, swelling power, water-holding capacity, and ash content. *Curcuma amada*, with the greater swelling power of its starch, can be used in the food industry whereas starch from *C. caesia*, given its low solubility, will be useful not only in metabolic products but also in textiles because its smaller granules can penetrate fabrics easily, imparting desirable stiffness to clothes. In general, *Curcuma* species appear to be promising alternative sources of starch for commercial use not only because they offer many desirable physicochemical properties but also because they are easy to cultivate, widely adapted and resilient to adverse climatic conditions.

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